



3D Printing

Purpose of the Module: Introduce 3D printing to pupils

Achievable results/ learning outcomes:

- Pupils learn how to use Voxelizer's software features and its user interface;
- Pupils learn to design a two-dimensional sketch and use assistive tools;
- Pupils learn to edit 3D models;
- Pupils can prepare a product for 3D printing;
- Pupils learn to use G-code;
- Pupils can assemble parts of the model and choose the appropriate production method.

Tasks

- Teach the basics of 2D/3D modelling
- Make a 2D/3D model for 3D printing
- Edit a chosen 2D/3D model
- Teach the basics of 3D printing
- Analyze 3D printing materials
- Prepare 3D models for printing
- Make a 3D printed part/assembly

Module Duration

4 – 6 academic hours

Name of the school subject this module may be used for

- Mathematics
- Physics
- Informatics

3 themes/subsections of module

1. Computer-assisted design

1) Achievable results/ learning outcomes

- *Pupils learn to create and edit 2D/3D models.*

2) Tasks

- *Teach the basics of 2D/3D modelling*
- *Make a 2D/3D model that can be used for 3D printing.*
- *Edit a chosen 2D/3D model*

3) Duration

- *2 academic hours*

4) Name of the school subject this module may be used for

- *Mathematics*



- *Physics*
- *Informatics*

2. 3D printing

- 1) Achievable results/ learning outcomes
 - *Pupils can understand 3D printing principles*
 - 2) Tasks
 - *Teach the basics of 3D printing*
 - *Analyze 3D printing materials*
 - 3) Duration
 - *1 academic hour*
 - 4) Name of the school subject this module may be used for
 - *Physics*
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1. **“Voxelizer” software essentials**
 - 1) Achievable results/ learning outcomes
 - *Pupils learn how to use “Voxelizer” software independently*
 - 2) Tasks
 - *Introduction to software’s user interface*
 - *Preparing 3D models for printing*
 - *Making a 3D printed part/assembly*
 - 3) Duration
 - *2-3 academic hours*
 - 4) Name of the school subject this module may be used for
 - *Physics*
 - *IT or computer science*

Computer-assisted design

Computer-aided design (CAD) is used in a variety of industries to assist with the design process. CAD software allows the user to build an entire model in an imaginary space and visualize properties such as height, width, distance, material and colour before this model is used.

A computer scientist named Ivan Sutherland created the first computer graphic program, known as “SketchPad” in 1962. It allowed people to both write and draw simple figures directly on a screen with the help of a special pencil. This marked the start of all future CAD software.

At first, CAD was used for research purposes only, however, in the 1970s, several big automotive and aerospace engineering companies started developing their software. From the 1980s onwards CAD was also applied to many other industries. CATIA and AutoCAD were

created a little bit later, in the 1990s, and have become important design tool that has been widely used in a variety of workplaces since.



There are several benefits of using CAD as a design and analysis tool:

- **Allows the user to easily imagine the result:** It allows you to create and visualize 2D or 3D objects and make as many changes as you need with less effort than drawing it on paper with a pencil.
- **The user can make their work as detailed as they want:** Digital representation in CAD closely resembles real life, making it accurate up to a certain level. You can also add as much fine detail as needed.
- **Permits optimization:** Finding mistakes during the design process is usually quite difficult. Although it is not perfect, however, CAD software can help to solve that issue. The more sophisticated CAD programs even allow you to run simulations to test for possible imperfections.
- **Can be easily adapted to be used in many professional settings:** CAD software is available for almost every professional sector with specialized features and suitable tools, making it easy to apply to different fields.
- **Provides tangible results:** You have the possibility of bringing your digital design to the real world in the form of a physical object with the help of fabrication technologies and CAM software, which would be more difficult and expensive with traditional fabrication methods.



Why is this technology so important for many professionals? The biggest sectors that often use CAD are

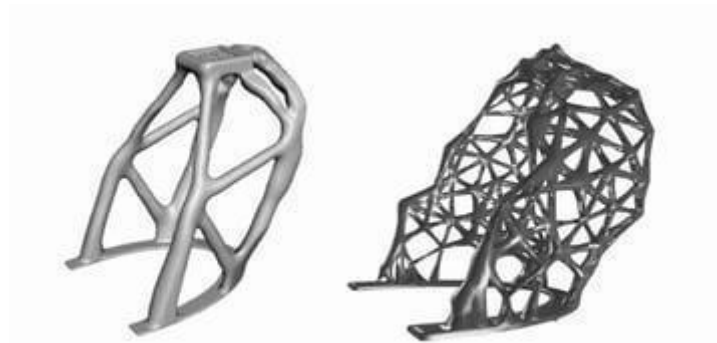
- **Architecture:** When talking about CAD, Architecture is one of the most demanding subjects. To fully accomplish the project and include all the small design details in it, architects often rely on software.
 - Example: Large design companies usually work with BIM (Building information modelling) software like Revit or ArchiCAD to work more effectively, but small design firms more typically combine different tools. For example Architect Eric Reinholdt, who runs a YouTube channel and owns a studio called 30×40 Design Workshop, claims to use AutoCAD, SketchUp Pro, Adobe Photoshop, and Lightroom for his daily work.
- **Product design:** Industrial designers use CAD software not only to visualize an object but also to understand and verify its functions. Tools like Fusion 360, Inventor, or SolidWorks are the most commonly used.
 - Example: Grovmade is a company focused on developing high-quality wooden products. Their CAD and CAM tool of choice is Fusion 360 as it makes their work more efficient.
- **Graphic design:** Professional graphic design also makes use of 2D or 3D CAD software to create visualizations. This kind of software allows typography, adding shapes and effects, and choosing different backgrounds to improve the visuals.
 - Example: Matthew Encina is a designer and content creator who uses Adobe Photoshop, Illustrator, and After Effects as his main tools to develop branding material and provide an interactive experience for his clients.
- **Engineering:** Given the many and diverse engineering fields, the types of CAD programs used by engineers are also many and varied. Some of the most common subjects include infrastructure, buildings, circuits, telecommunication networks, thermodynamics, mechanical parts, medical devices, and manufacturing.
 - Example: The Engineering Research Center of Brown University was designed using BIM. This complex project was finished by the architecture firm Kieran Timberlake, and the company named BuroHappold Engineering. They both worked on the design and the construction together and used Revit models.



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CAD has proven to be a problem solver for many professional areas, so it's generally difficult to find drawbacks. There are, however, some disadvantages to using it:

- **Licensing:** Higher-end tools typically come with steep prices, whether subscription-based or one-time fees. The main exception to this is if they're being used for educational purposes.
- **Time:** Learning how to use CAD and CAM tools takes time. Creating and executing suitable designs has its cost, including the time spent on training.
- **Appliances:** To perform at their best, CAD and CAM tools often require powerful (and expensive) equipment.



These days, CAD is constantly changing, bringing updates and new features in with every new version of a particular tool. And that is excluding the huge range of options available for professional use.

Tools are becoming more powerful by the year. Among the new projects, some even involve AI, as is the case with Autodesk's experimental software Dreamcatcher. It is not only a visualization tool but also a design program that suggests the best solution when given specific variables.

According to Andreas Vlahinos, CTO at Advanced Engineering Solutions, someday we'll need CAD software to reproduce human intelligence to complete certain tasks. Thus, it is likely that "smart" CAD software will be created in the near future.



Questions:

1. What is computer-aided design mainly used for?

Answer: Computer-aided design (CAD) is used in a variety of industries to assist with the design process.

2. What was CAD first used for?

Answer: Rather than being applied to commercial purposes, at the beginning CAD was used for research only.

3D printing

3D printing is an additive technology used to manufacture parts. ‘Additive’ means that it doesn’t require a block of material or a mould to produce physical objects, it simply stacks and fuses layers of material. It’s typically fast, with low and fixed setup costs. It can create rather complex geometries compared to ‘traditional’ technologies, with an ever-expanding list of materials. In the engineering industry, it is often used to create lightweight geometries and make prototypes.

‘3D printing is commonly associated with maker culture, hobbyists and amateurs, desktop printers, accessible printing technologies like FDM and low-cost materials such as ABS and PLA (we’ll explain all those acronyms below). This is largely due to the standardization of 3D printing that happened because of affordability. Desktop machines, such as the original MakerBot and Ultimaker, sprung from the RepRap movement and led to the popularity of 3D printing in 2009.

By contrast, additive manufacturing (AM) is almost always associated with commercial and industrial applications.



3D printing technologies are also called 'Rapid prototyping'. This dates back to the early history of 3D printing when the technology first emerged. In the 1980s, when 3D printing techniques were first invented, they were referred to as rapid prototyping technologies because the technology was not suitable for producing parts. It could only make prototypes back then. Nowadays, 3D printing has matured and is being used as a means to produce many different types of production parts. Other manufacturing technologies (such as CNC machining) may be used for prototyping as well. It has become cheaper and more accessible over the years too. Therefore, while some people still use 'rapid prototyping' to refer to 3D printing, this title is evolving. It will soon refer to and include all forms of immediate prototyping.

3D printing was a key solution that accelerated industrial product development through faster prototyping. Even though a few other patents existed beforehand, Chuck Hull is typically credited with the invention of the 3D printer as his Stereolithography Apparatus (SLA) was patented in 1984.

Despite Chuck's fame, many technologies were being developed simultaneously in the late 1980s. Furthermore, several companies were founded in this period and as a result, it solicited further development of the technology.

- 1981 - the first patent for a device using UV light to cure photopolymers was awarded to Hideo Kodama in Japan. He designed it for 'rapid prototyping' as it was intended for making models and prototypes, but no interest was shown and the patent was abandoned.
- 1984 - French inventors Alain Le Mehaute, Olivier de Witte, and Jean Claude André submitted a patent in which, like Hideo's, UV light was used to cure photopolymers. General Electric abandoned the patent claiming it lacks significant business potential.

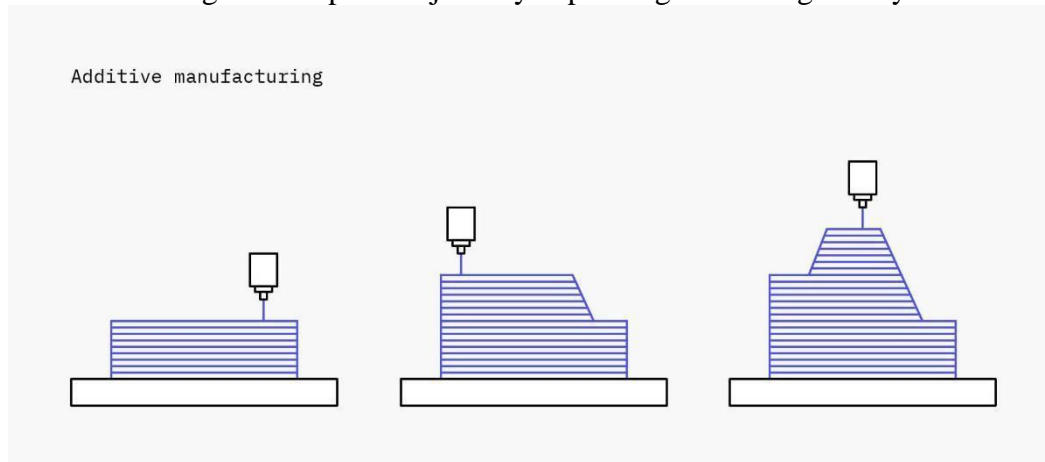
- 1984 - only a few weeks after Le Mehaute, American Charles ‘Chuck’ Hull filed his patent for an ‘Apparatus for Production of Three-Dimensional Objects by Stereolithography’, thus also coining the term ‘stereolithography’ (SLA).
- 1987 - Hull invented the STL file, and in the same year founded 3D Systems.
- 1987 - American Carl Deckard filed a patent for Selective Laser Sintering (SLS), and in the same year co-founded Desktop Manufacturing (DTM) Corp. (acquired by 3D Systems in 2001).
- 1989 - American S. Scott Crump submitted a patent for Fused Deposition Modeling (FDM), and in the same year founded Stratasys with his wife.

From the late 1980s to the early 1990s the industry quickly became profit-orientated. The first machines were big and expensive and their makers competed for industrial prototyping contracts with mass-market manufacturers in the automotive and health industries as well as aerospace engineering and consumer goods.

- 1987 - 3D Systems released the first commercial SLA printer, the ‘SLA-1’.
- 1992 - The FDM patent was finally granted to Stratasys, which led them to release the first FDM printer, the ‘3D Modeler’.
- 1992 - DTM released the first commercial SLS printer, the ‘Sinterstation 2000’
- 1994 - German company Electro Optical Systems (EOS), founded in 1989, released its ‘EOSINT M160’, the first commercial metal 3D printer

From 2018 onwards, the hype around 3D printing had disappeared from the mass media but businesses of all sizes are more interested than ever. There are thousands of companies producing printers and offering all sorts of services that use 3D printing technology. Additive manufacturing has only been around since the 1980s, so the manufacturing methods developed before it are often referred to as traditional manufacturing. To understand the major differences between additive and traditional manufacturing, let's separate all methods into 3 groups: additive, subtractive and formative manufacturing.

Additive manufacturing builds up 3D objects by depositing and fusing 2D layers of material.

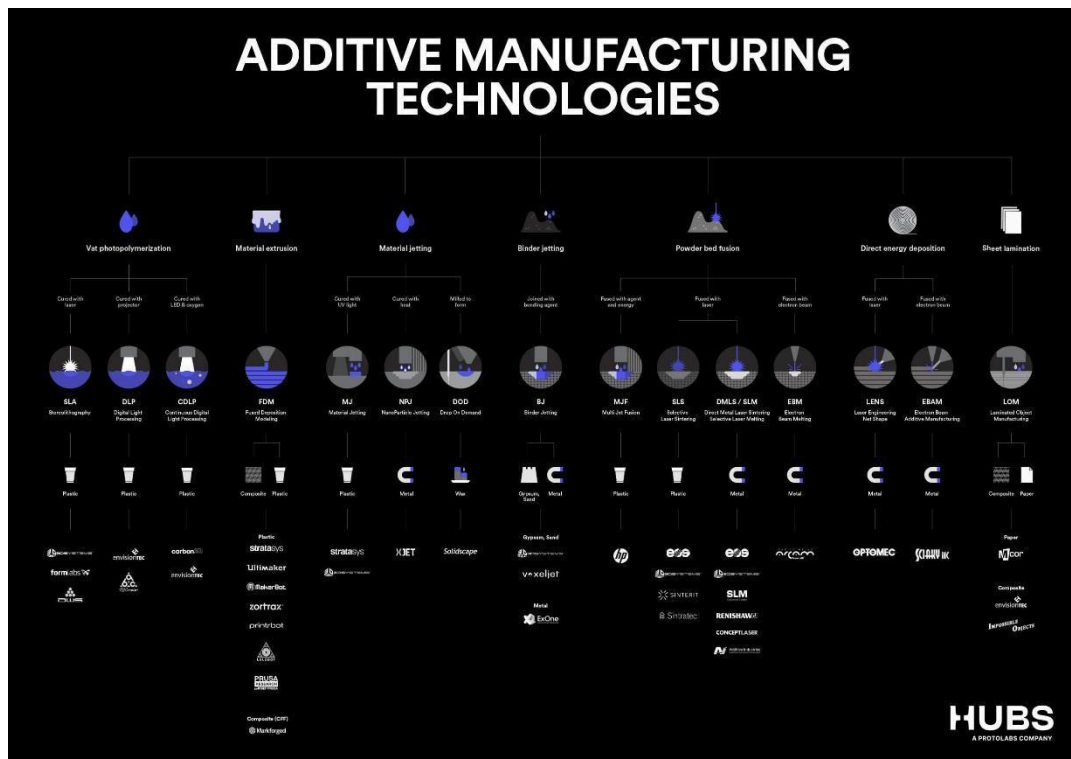


This method has almost no startup time or costs, making it ideal for prototyping. Parts can be made rapidly and discarded after use. Parts can also be produced in almost any geometry. This is also one of the core strengths of 3D printing.

One of the biggest disadvantages of 3D printing is that most parts are naturally anisotropic or not fully dense, meaning they usually lack the material and mechanical properties of parts made via subtractive or formative techniques. Due to changes in cooling or curing conditions, several prints of the same part tend to differ slightly. Since these parts rarely turn out identical, it harms consistency and repetition.

3D printers can be categorized into one of the several types based on the process they use:

1. **Vat Polymerization:** liquid photopolymer is cured by light
2. **Material Extrusion:** molten thermoplastic is deposited through a heated nozzle
3. **Powder Bed Fusion:** powder particles are fused by a high-energy source
4. **Material Jetting:** droplets of liquid photosensitive fusing agent are deposited on a powder bed and cured by light
5. **Binder Jetting:** droplets of the liquid binding agent are deposited on a bed of granulated materials, which are later sintered together
6. **Direct Energy Deposition:** molten metal simultaneously deposited and fused
7. **Sheet Lamination:** individual sheets of material are cut to shape and laminated together





Among the 3D printing processes, there are seven primary ones. Within each type of these process, there are unique technologies, and for every unique technology, many different brands are selling similar printers.

Photopolymerization is the process of a photopolymer resin being exposed to a certain wavelength of light and becoming solid.

Stereolithography (SLA), direct light processing (DLP) and continuous direct light processing (CDLP) are additive manufacturing processes that fall under the category of vat photopolymerization. In SLA, an object is created by selectively curing a polymer resin layer-by-layer using an ultraviolet (UV) laser beam. DLP is similar to SLA but uses a digital light projector screen to flash a single image of each layer all at once. CDLP is a lot like DLP but relies on the continuous upward movement of the build plate. All vat photopolymerization processes are good for producing fine details and smooth surface finishes, making them ideal for jewellery and medical applications.

Advantages

- Smooth surface
- Fine details
- Good for prototyping of IM

Disadvantages

- Brittle
- Usually requires support
- UV sensitive
- Takes a while to post-process

Powder bed fusion (PBF) technologies use a heat source to induce fusion (sintering or melting) between the particles of a plastic or metal powder, one layer at a time. Selective Laser Sintering (SLS), electron beam melting (EBM) and multi-jet fusion (MJF) all fall within this technology. The metal 3D printing processes selective laser melting (SLM) and direct metal laser sintering (DMLS) also use powder bed fusion to selectively bind metal powder particles.

Advantages

- Strong parts (nylon)
- Complex geometry
- Easily adaptable (suitable and fits size)
- No support

Disadvantages

- Longer production time
- Higher cost (machines, material, operation)



Material extrusion technologies squeeze a material through a nozzle and onto a build plate, layer by layer. Fused deposition modelling (FDM) falls under this category and is the most widely used 3D printing technology.

Advantages

- Fast
- Low cost
- Common thermoplastics

Disadvantages

- Rough surface finish
- Anisotropic
- Usually requires support
- Cannot be easily adapted to true size
- Limited accuracy

Material jetting technologies use UV light or heat to harden photopolymers, metals or wax, building parts one layer at a time. Nanoparticle jetting (NPJ) and Drop-on-demand (DOD) are two other types of material jetting.

Advantages

- Realistic prototypes
- Excellent details
- High accuracy
- Smooth surface finish

Disadvantages

- High cost
- Brittle mechanical properties

Binder jetting uses an industrial printhead to drop a binding adhesive agent onto thin layers of powder material. Unlike the other 3D printing technologies, binder jetting does not require heat.

Advantages

- Full-colour options
- Range of materials
- No support
- No warping or shrinking

Disadvantages

- Low part strength



- Less accurate than material jetting

Direct energy deposition (DED) creates 3D objects by melting powder material as it is deposited. It is mostly used with metal powders or wire and is often referred to as metal deposition. Laser-engineered net shape (LENS) and Electron Beam Additive Manufacture (EBAM) also fall within this category.

Advantages

- Strong parts
- Range of materials
- Larger parts

Disadvantages

- High cost
- Poor surface finish

Selecting the optimal 3D printing process for a particular part can be difficult as there's often more than one suitable process but each one will produce subtle variations in cost and output. Altogether, there are three key things to consider:

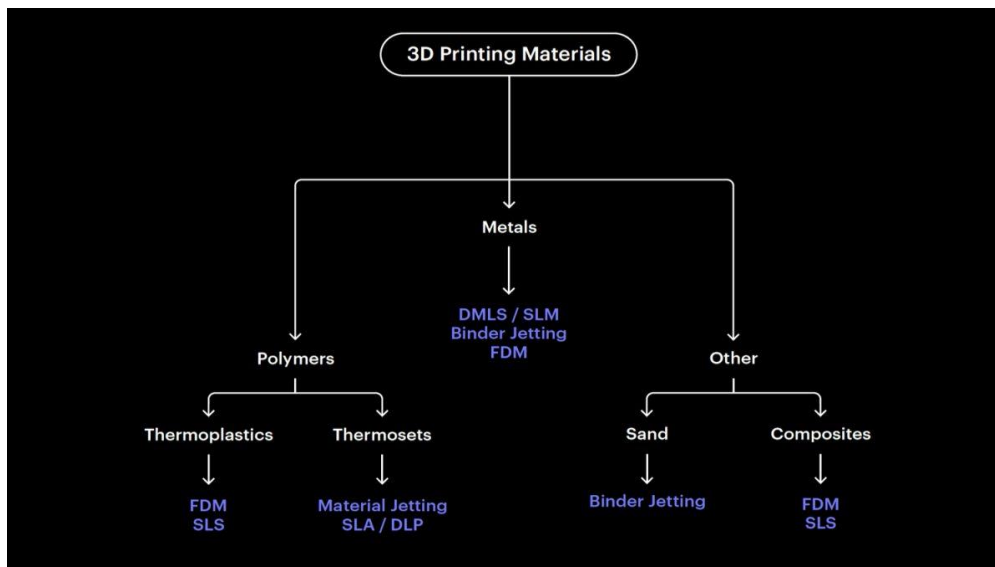
- The required material properties: strength, hardness, impact strength, etc.
- The functional & visual design requirements: smooth surface, strength, heat resistance, etc.
- The capabilities of the 3D printing process: accuracy, build size, etc.

These should be consistent with the three most common methods for selecting the right process:

- By required material
- By required functionality or visual appearance
- By required accuracy or build size

The number of available 3D printing materials grows quickly every year as market demand for specific materials and mechanical properties stimulates the advancement in material science. This reason makes it impossible to give a complete overview of all 3D printing materials. However, each 3D printing process is only compatible with certain materials so it can be solved quite easily by simple reasoning.

Thermoplastic and thermoset polymers are by far the most common 3D printing materials, but metals, composites and ceramics can also be 3D printed.



Another way of categorizing materials is by their properties: cheap, chemically resistant, dissolvable, flexible, durable, heat resistant, rigid, water resistant, and UV resistant. When used in the industrial setting, it usually requires durable plastics such as Nylon 12, whereas the majority of amateurs use either PLA or ABS, which are the most common materials used in FDM 3D printing.

So where is 3D printing today? Is the hype over? Yes, and by now the technology is reaching its prime. Hubs have been around since 2013, and we've produced a 3D Printing Trend Report every year since 2017. Over those years we've watched technology reach the height of the hype cycle, drop through the 'trough of disillusionment, and bounce back to where it is now - on the 'slope of enlightenment.

The hype of the previous years was based on the idea of widespread consumer adoption. This was a misleading vision of where technology could add value to the world. The usage of 3D printing is the most promising when applied to relatively narrow and definite roles in the world of manufacturing.

Questions:

1. What is 3D printing?

Answer: 3D printing is an additive technology used to manufacture parts.

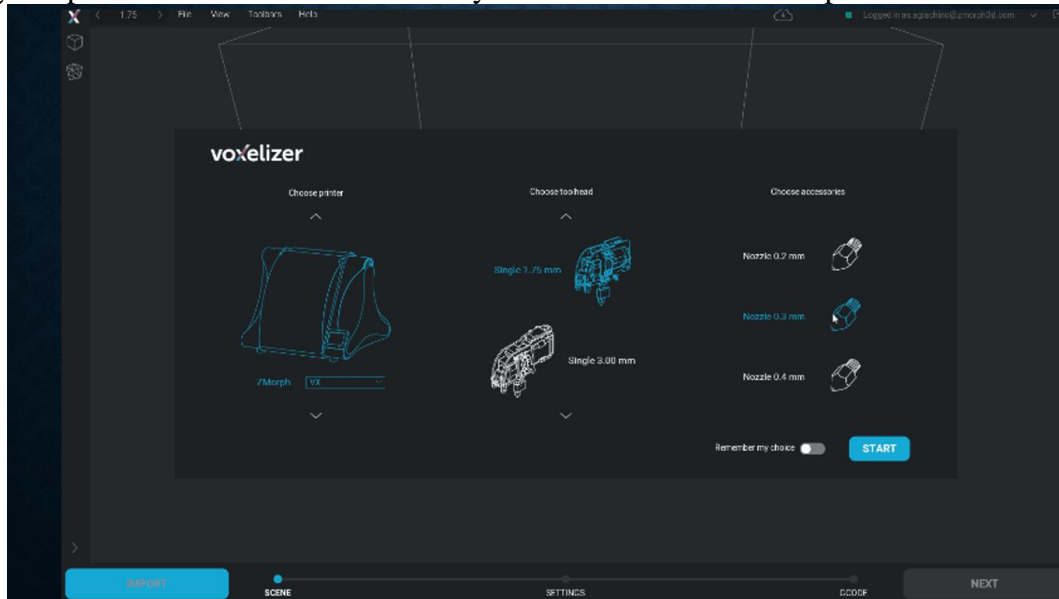
2. What does 'additive technologies' mean?

Answer: 'Additive' means that the production of the physical object doesn't require a block of material or a mould, as the process is achieved through stacking and fusing layers of material.

"Voxelizer" software essentials

Voxelizer 2 is software designed for multi-material and multi-workflow digital fabrication. It is made for use in 3D printing, CNC, laser cutting and thick paste extrusion, all using a single pipeline.

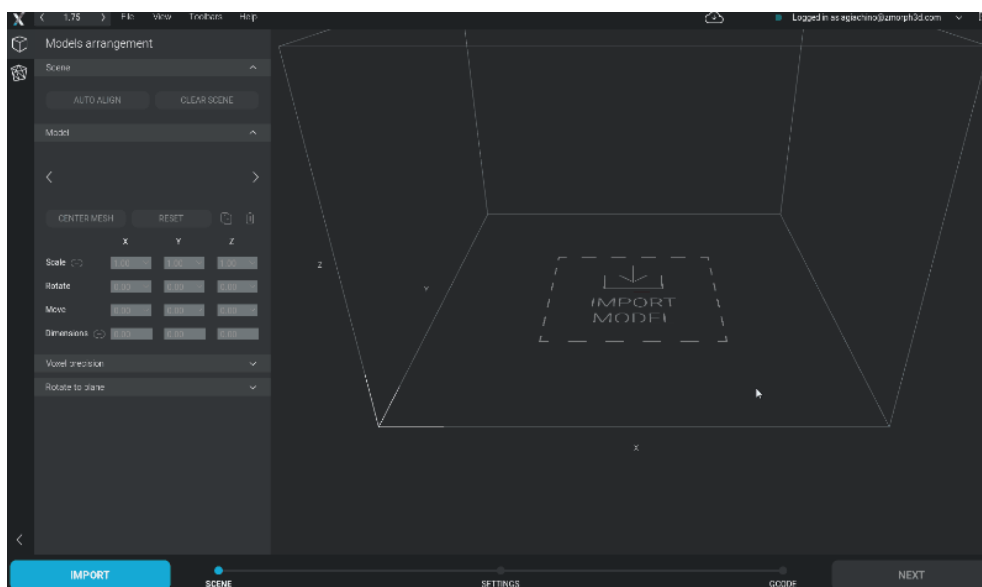
In this short introduction, we will take a quick look at what you can achieve with Voxelizer 2. When you open Voxelizer for the first time you will see the Welcome splash screen.



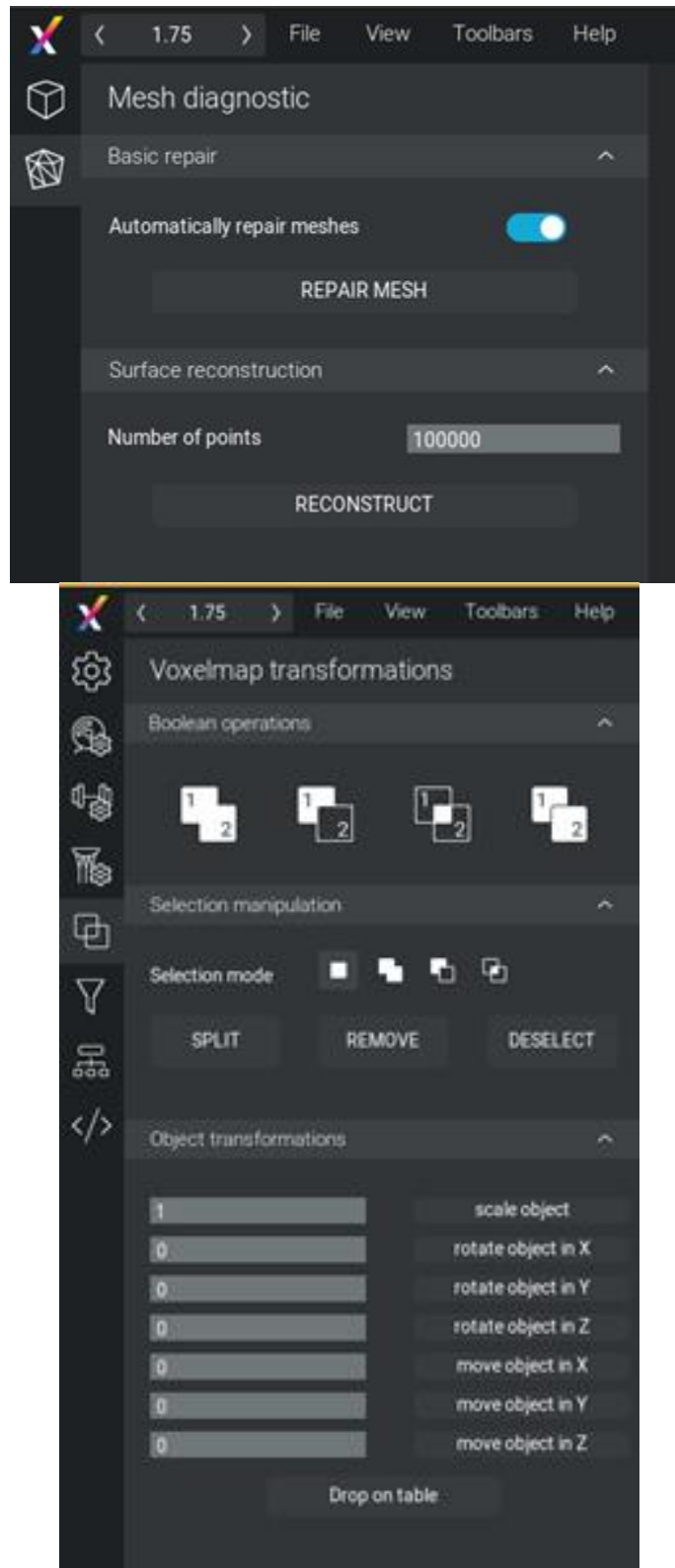
Here you can choose your printer/machine (we keep adding new ones) and tool head, which will also affect the specific workflow you will be using: 3D printing, CNC, Laser or thick paste extrusion.

In our example, we will choose a 3D printing, single extrusion workflow. These principles are also valid for/applicable to other projects.

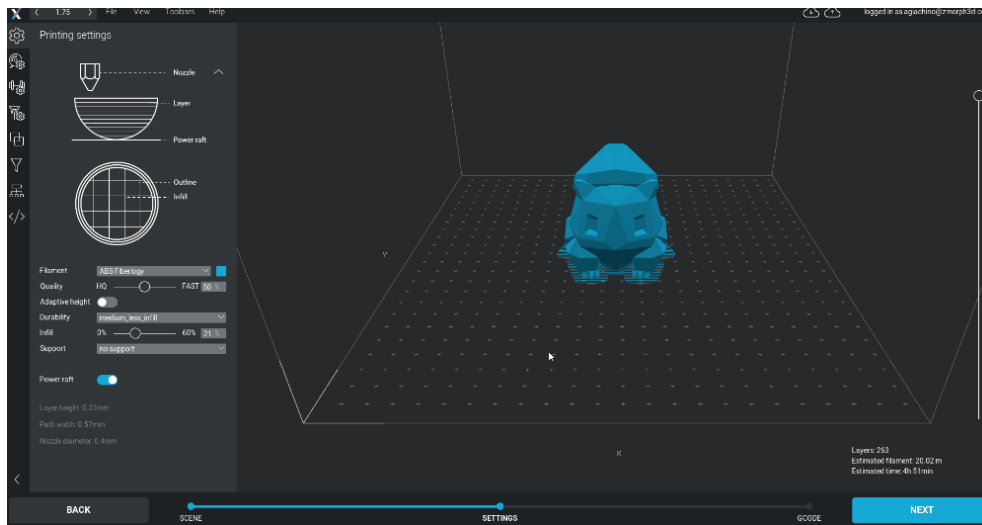
Once you have chosen your workflow you are in the "Scene Editor". Here you can import and set up your model by applying basic transformations like rotation and scaling.



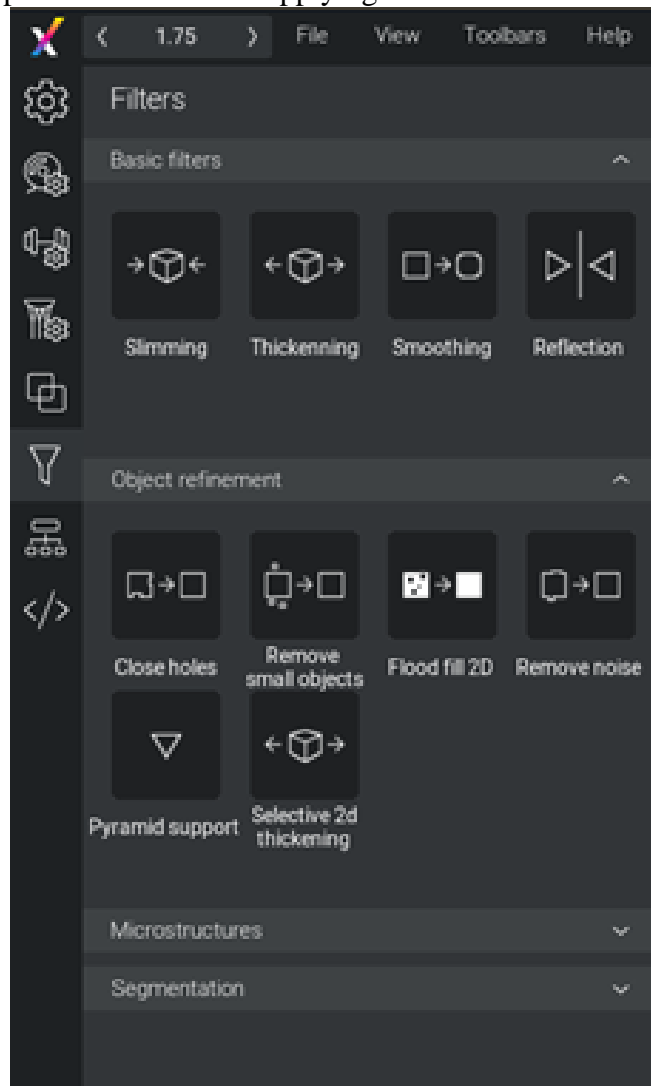
If your mesh is damaged you can try to repair it under the *mesh diagnostic* tab.



Once you have set up your scene you will move to the Settings view. This is the core of Voxelize, where you can benefit the most from the voxelization process.



Try one of the many filters to refine, repair and fix your mesh, or use them to achieve powerful visual results. One example of this would be applying a microstructure.



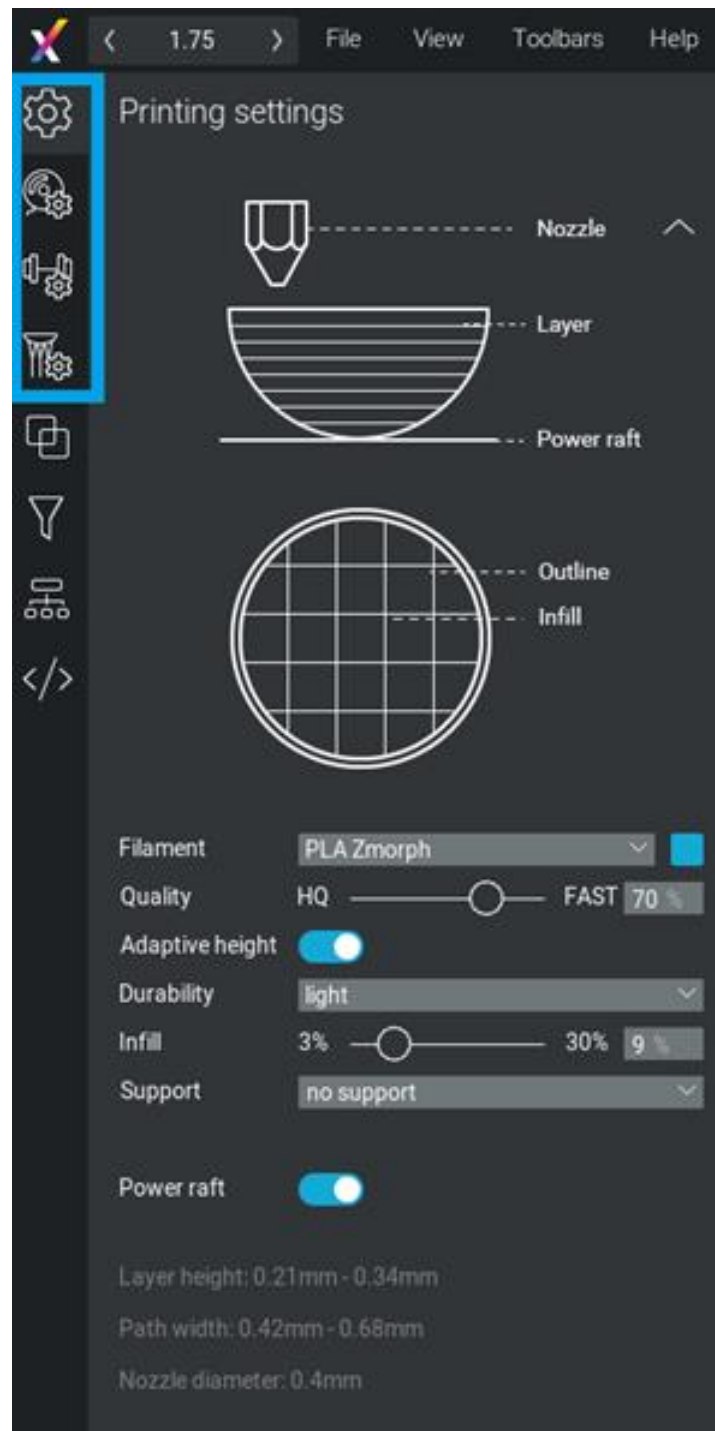


To fine-tune your model you can go into the Voxelmap Transformations tab. Select the voxels directly with your mouse by dragging and pressing SHIFT (to add voxels), CTRL (to remove voxels) or 'q' to activate the sphere selection mode (use the mouse wheel to change the size of the sphere).



Once you have applied all the necessary transformations to your model, it is time to set it up for printing under the *Printing Settings* tab.

To make the generation of G-code easier for the user, Voxelizer works with presets. You can either choose one of the already available presets or create your own.

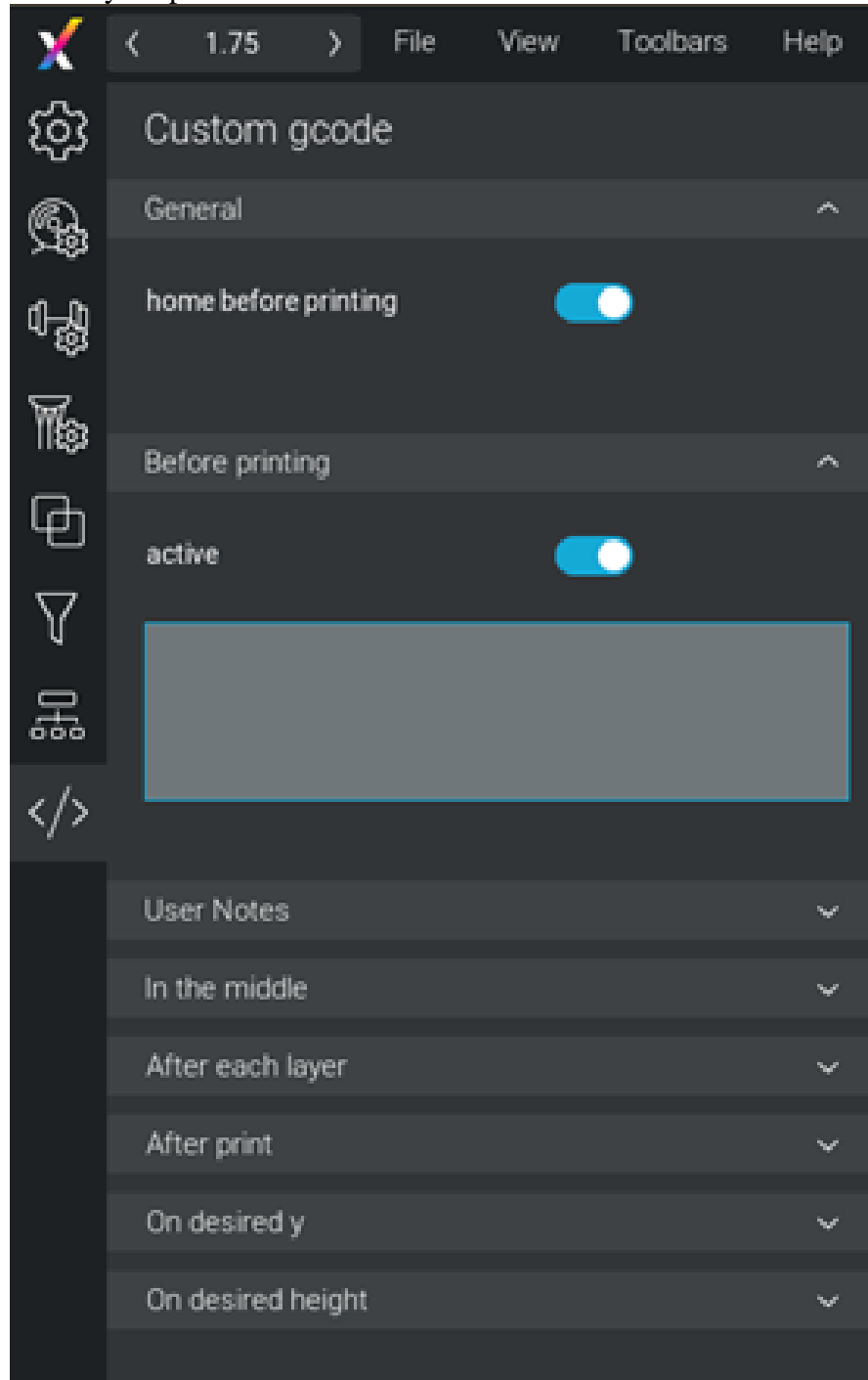


In the Filament Settings, you will find all the parameters that are necessary to achieve the best printing quality.

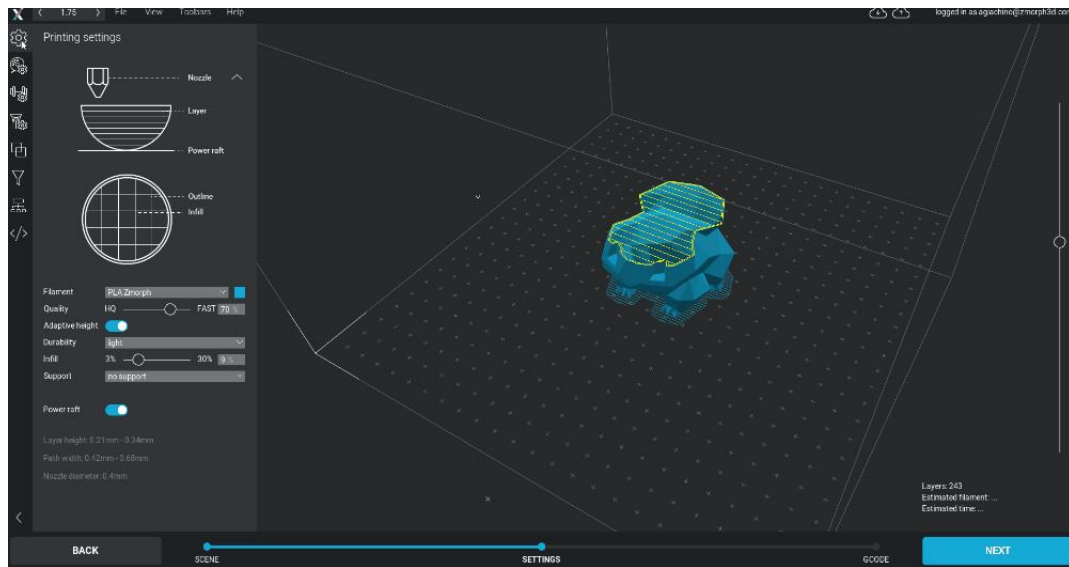
The Durability Settings are about the density and strength of your model: here you can choose the type and set the quality of your infill.

In the Support Settings, you define the type and characteristics of your support. In Voxelizer 2 we have upgraded the support, two of the new types are called the Tree Support and the Lattice Support. These provide many support possibilities. Give them a try.

If you want extra control over your print, you can go to the Custom G-code panel and add specific commands for your printer.



When everything is set you can click *NEXT* and the G-code will be generated.
Under the Diagnostic tab, you can inspect it and make sure that everything is as desired.
Now you can save your G-code and print your model!

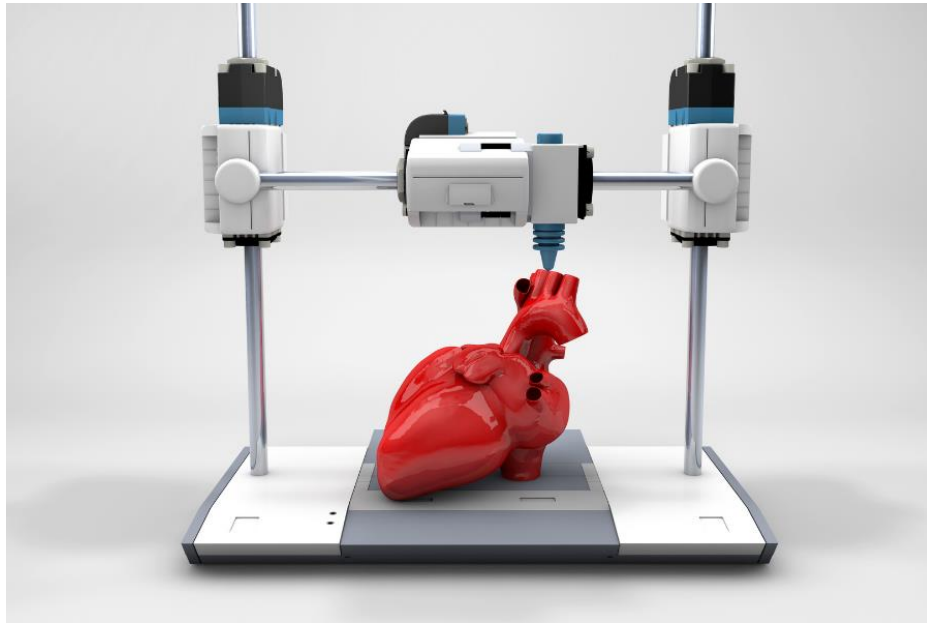


Question:

1. What is Voxelizer software used for?

Answer: It was designed for multi-material and multi-workflow digital fabrication.

SKILLS AND ABILITIES



People working with 3D printers must possess these skills and abilities:

- A high mechanical aptitude.
It is one of the most important skills if you are interested in using a 3D printing technology. Students need to have a good understanding of how all parts of the printer work and the functions of this technology. It proves to be a really useful skill if the printer breaks down and needs to be repaired.
- Strong attention to detail to ensure that the finished products are manufactured correctly.
- Effective communication skills.
- Strong organizational abilities to successfully manage all features of the printing process.
- Read and understand work-related materials.
- Understand spoken and written information.
- Notice when something is wrong or anticipate what is likely to go wrong.
- Use reasoning to discover answers to problems that may arise.
- Determine the causes of technical problems and find solutions for them.
- Have a good knowledge of mathematics and be able to apply mathematical methods or formulas to solve certain problems.
- Have a good imagination
- Be able to visualize things, and anticipate how the product will look like in the initial production stages, and how the project will look once it is already completed
- Determine when and what kind of maintenance is needed for the equipment.
- Manage equipment, materials and other work-related things and do not lose them.

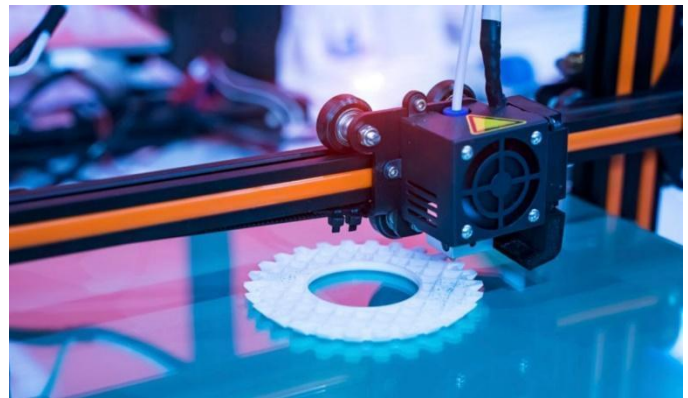


<https://midf.ktu.edu/news/atsiveria-beribes-3d-spausdinimo-galimybes/> (LT)

<https://bernardmarr.com/7-amazing-real-world-examples-of-3d-printing/> (EN)

TYPICAL WORK DAY

3D printing is a relatively new technology when it comes to manufacturing products or their parts. It involves using computer-aided design (CAD) and allows to print of products in layers. A 3D printing technician usually supervises the printing process and offers suggestions regarding what products a company can produce through a 3D printer. It is a role based on manufacturing or production.



One of the primary duties of a 3D printing technician is creating the daily schedules for the printers and evaluating customers' designs to make sure that they are compatible with 3D printing. Other job work responsibilities may include providing ideas on how to make the printing process more efficient, performing such tasks as sandblasting or polishing the product or its part and collaborating with production personnel to establish new work processes and guarantee that workflow is well organized and running smoothly. 3D printing technicians are also required to assist with maintaining the production environment, which entails cleaning and repairing the 3D printers. Technicians sometimes work with the product development team, aiding them with the creation of design processes. 3D Technicians may also be required to work in other production roles as needed in case of employee shortage.

WHERE TO START? CAREER PATH



A 3D printing technician will typically need a bachelor's degree in fields such as engineering, fine arts, or computer science. Relevant work experience in manufacturing or production also would be beneficial to work as a 3D printing technician.



Depending on the country, similar job positions and positions that require a similar set of skills are printing press operators, 3D artists, AutoCAD designers and manufacturing or production technicians.



Video: How to 3D print human tissue

https://www.youtube.com/watch?v=uHbn7wLN_3k&ab_channel=TED-Ed



Part III

There are no vocational or higher education schools in Lithuania that currently provide 3D printing courses.

Sometimes 3D printing modules are included as a part of various design and engineering courses such as mechanical engineering, industrial design, vehicle or aviation engineering as well as production engineering and similar programmes.

Even though courses focusing solely on 3D printing are not provided, 3D printing technologies are used in many manufacturing, production and design industries (e.g. architecture or dental technology) so 3D printing skills and knowledge may even be applied there.

Useful resources:

- Basics of 3D Printing

https://www.youtube.com/watch?v=nb-Bzf4nQdE&ab_channel=ThomasSanladerer (EN)

- Beginner's guide: which 3D printer should you get?

https://www.youtube.com/watch?v=rkw4cVZ1A5Q&ab_channel=3DPrintedTabletop (EN)

- The Bioprinting Process

https://www.youtube.com/watch?v=BDdMxjq_M4g&ab_channel=AspectBiosystems (EN)

https://www.youtube.com/watch?v=FjjYHwwT73k&ab_channel=USPTOvideo (EN)

- Tik tok compilation of cool things which can be manufactured with a 3D printer

https://www.youtube.com/watch?v=IHdRqezAwb8&ab_channel=TikTokTour (EN)

- 3D Printing of a steel part that is impossible to make by using a CNC Machine

https://www.youtube.com/watch?v=lnE1om0KM5c&ab_channel=TITANSofCNCMACHINING

Sources

<https://bestaccreditedcolleges.org/articles/3d-printing-technician-salary-training-job-description.html>

<https://fmed.ktu.edu/studies/>

https://www.google.com/search?q=dentist+technician&rlz=1C1CHZN_enLT974LT974&oq=dentist+technician&aqs=chrome..69i57j0i457i512j0i512l6j0i22i30l2.3701j0j4&sourceid=chrome&ie=UTF-8



<https://www.futurelearn.com/info/courses/getting-started-with-digital-manufacturing/0/steps/184102>
<https://medium.com/techtalkers/three-ways-3d-printing-is-changing-the-world-83e0fb6aec3c>
<https://theconversation.com/how-3d-printing-is-transforming-our-relationship-with-cultural-heritage-112642>
<https://bernardmarr.com/7-amazing-real-world-examples-of-3d-printing/>
<https://www.cpacanada.ca/en/news/pivot-magazine/2021-10-15-printing-mosaic-manufacturing>

PRACTICAL TASKS

many things can be created by using 3D printing technology, for example, household items, toys and other useful items. Have fun and let your creativity flow.

Examples

A can holder:

https://www.youtube.com/watch?v=YpLGSiwsLXk&t=2s&ab_channel=MakeAnything (EN)

Cute 3D Baby Yoda:

<https://www.gambody.com/blog/top-20-baby-yoda-3d-printing-models-stl-files/> (EN)

3D printed biodegradable flower pots made from PLA wood:

<https://www.contemporist.com/biodegradable-planters-made-from-3d-printed-wood/> (EN)

First-ever 3D printed home:

https://www.youtube.com/watch?v=bFe6pwwVgwo&ab_channel=ClickOnDetroit%7CLocal4%7CWDIV (EN)

10 Useful 3D Printed Tools 2021:

https://www.youtube.com/watch?v=UnAP5tFpVYk&ab_channel=3DPrints%26Builds (EN)

Polylactic Acid

Polylactic Acid (commonly known as PLA) is one of the most popular materials that are usually used in 3D printing. It is the main filament that is mostly used for most extrusion-based 3D printers because it can be printed at a low temperature and does not require a heated bed.

What is PLA?

<https://all3dp.com/2/what-is-pla-3d-printing-materials-simply-explained/> (EN)

However, you should bear in mind that:

- Items made of PLA cannot withstand high heat so should not be left in the direct sunlight in summer.



- PLA is a relatively soft plastic: avoid applying high pressure or dropping it because the item might break apart.
- PLA is biodegradable so items may show wear and tear after a while.

Preparation for practical tasks

- Before using a 3D printer, students should find out what model of 3D printer they will be using as well as its inner and outer structure.
- The teacher should explain what technical and non-technical issues may arise when using the printer; introduce the guidance rules for safe usage; explain how to install (and assemble) the printer, if needed.
- The students should be introduced to the parameters and possible options of the 3D printer: either by using the control panel settings or the 3D printing software.

The basic settings of 3D printers are

- Dimensions
- Weight
- Printing technology
- Type of extruder
- Materials
- Number of nozzles
- Nozzle diameter
- Filament diameter
- Max. head temperature
- Max. print speed
- Work field
- Supported file formats

Useful terms:

- **Infill:** The area within a 3D-printed object that connects the top, bottom, and side layers. This creates a rigid structure and determines the durability of the print.
- **Layer Height:** The most important setting that affects print quality. It defines the distance between lines of extruded plastic in the Z-direction. Material extrusion 3D printers typically print layers between 0.1mm and 0.3mm high. A lower layer height translates to a smoother, higher-quality print. A higher layer height translates into a faster, low-quality print.
- **Axis Binding:** A problem associated with the X-, Y-, or Z-axis on a printer, in which the axis is unable to move freely or perform a given movement.



- **ABS:** Acrylonitrile Butadiene Styrene, a thermoplastic used for 3D printing.
- **Bridging:** Bridging occurs in a 3D print when the filament is extended across an open area without support. The distance a print can bridge is determined by the hardware capabilities of the printer and the slicer settings.
- **Build Plate/Print Bed:** The surface where the printer deposits the materials used for printing
- **Cooldown:** The process of cooling down the hot end. Cooldown occurs automatically after a print is finished, can also be done manually after changing filament to prevent filament baking and clogs.
- **Extruder:** The assembly that handles feeding and extruding filament during a print. The extruder has two parts: the stepper motor and feeding system that pushes the material into the printer, and a hot end that heats and extrudes the material through a nozzle onto the build surface.
- **Filament:** A thermoplastic formed into a continuous wire and wound onto a spool so it is compatible with a 3D printer's extrusion system. Examples: ABS, PLA, TPU
- **Fill Density:** A percentage value that determines how much of the interior volume of a 3D-printed object is filled with material. This value can range from 0–100%, the recommended value is 5–25%.
- **Minimal Layer Time:** The least amount of time required of the printer to maintain the action on any layer of a printed object for the filament to sufficiently cool before fusing a layer on top of it.
- **Mesh:** A collection of polygons attached by edges and vertices that makes up a net-like surface area in CAD.
- **Print Speed:** The rate at which a 3D printer is capable of moving while extruding plastic. A print speed of 50mm/s will be successful on most FDM printers. A print speed of 20–30mm/s will produce higher quality prints.
- **Shell:** The sidewalls of a 3D printed model, created by the exterior edges of every layer.
- **Slicer:** A type of software (e.g. Cura, Repetier Host) that allows manipulation of a 3D model and converts the file type into a coordinate system (usually Gcode) that the printer can follow to create a model.
- **Support:** Additional removable structures that are printed to support overhangs or other parts of a model that do not make any contact with the build plate during the printing process.

Keep in mind:

The quality of the model, the thickness of the layers and printing time all depend on the accuracy.

A lower infill and fewer shells will reduce the weight but will also reduce the item's stability.

Useful information:



How to smooth PLA 3D prints:

<https://www.instructables.com/How-to-Smooth-PLA-3D-Prints/> (EN)

When to use raft:

<https://all3dp.com/2/3d-printing-raft-when-should-you-use-it/> (EN)

TASKS



1. Colourful turtle figurines

Class size: 10-15 students.

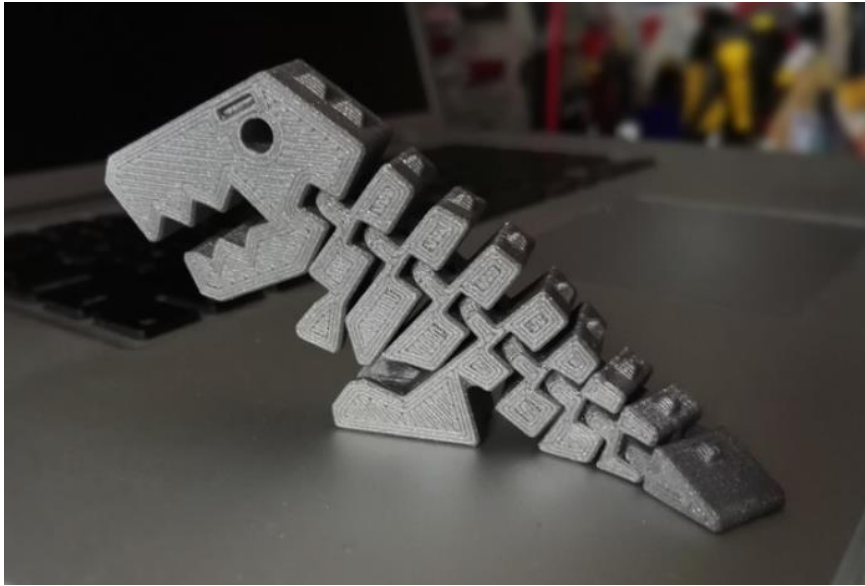
Individual work.

Duration: one day

- Material: PLA or any other suitable material
- Colour: Grey/green for the body and a bright hue for the turtle shell

Required tools:

- 3D printer
- Computer
- CAD software



2. Dinosaur figurine

Class size: 11-15 students.

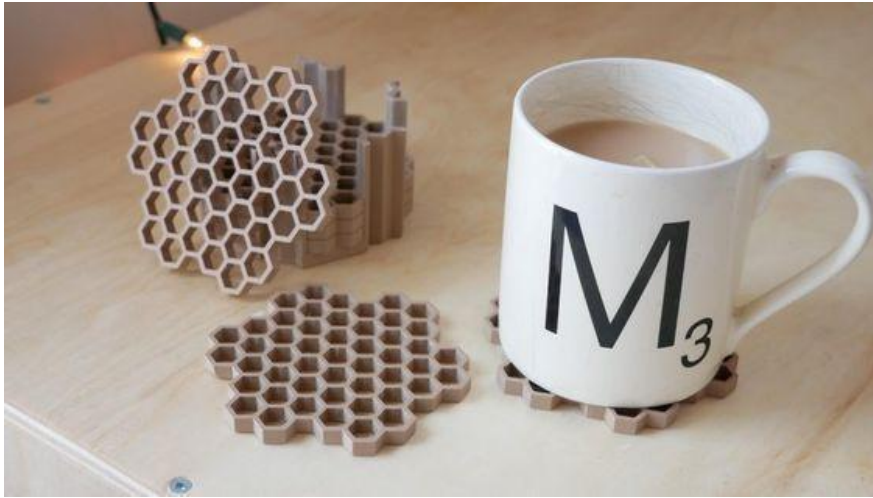
Could be completed as either individual work or group work. 3-4 students in a group.

Duration: one day

- Rafts: No
- Supports: No
- Resolution: 0.2 mm
- Infill: 15%
- Colour: dark grey/black/charcoal
-

Required tools:

- 3D printer
- Computer
- CAD software



3. Honeycomb drink coaster

Class size: 10-15 students.

Individual work.

Duration: one day

- Material: Wood PLA
- Colour: Brown/yellow

Required tools:

- 3D printer
- Computer
- CAD software



4. Pencil holder

Class size: 11-16 students.

Group work. 3-4 students in a group.

Duration: one day

- Material: PLA or other suitable materials
- Colour: Any

Required tools:

- 3D printer
- Computer
- CAD software



5. Desk organizer

Class size: 12-16 students.

Group work. 3-4 students in a group.

Duration: one day

- Material: PLA or other suitable materials
- Colour: Any

Required tools:

- 3D printer
- Computer
- CAD software



6. Earbud/earphone case

Class size: 10-14 students.

Individual work.

Duration: one day

- Filament: PLA (Polylactic Acid)
- Supports: No

Required tools:

- 3D printer
- Computer
- CAD software



7. Geometric Stand for Laptop

Class size: 12-14 students.

Group work. 3-4 students in a group.

Duration: one day

Can be used if you need to work with two screens at the same time.

- Material: PLA
- Colour: Any

Required tools:

- 3D printer
- Computer
- CAD software



8. USB Cable Holder

Class size: 11-14 students.

Individual work.

Duration: one day

- Material: PLA
- Infill: 10%
- Height: 0.2mm

Required tools:

- 3D printer
- Computer
- CAD software



9. Medieval knight pen holder

Class size: 12-16 students.

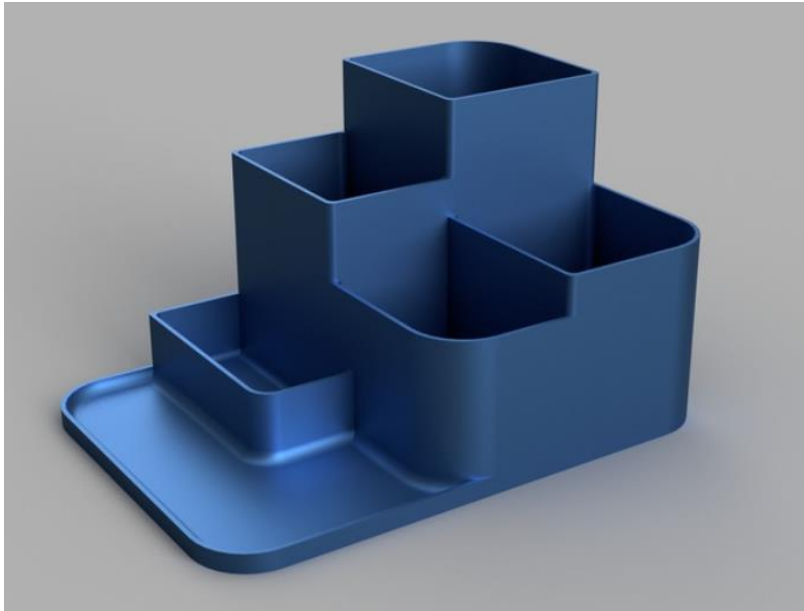
Group work. 3-4 students in a group.

Duration: one day

- Material: PLA
- Colour: dark grey/black/white

Required tools:

- 3D printer
- Computer
- CAD software



10. Desk organizer

Class size: 10-12 students.

Group work. 3-4 students in a group.

Duration: one day

- Material: PLA, metal or any other suitable material of choice
- Colour: Any
- Resolution: 0.25
- Infill: 10%
- Rafts: No
- Supports: No
- This print takes around 6hrs

Required tools:

- 3D printer
- Computer
- CAD software

To print this on a PrintrBot Simple Metal you will need to disable the Auto Levelling function to make use of the entire print bed. This can be done by simply commenting out the line "G29" in the start G-code. If PrintrBot was assembled well and has not been damaged, this shouldn't impact the print greatly.



11. Iceberg Ice Tray

An iceberg-shaped mold for ice cubes, frozen juice lollies, jelly, ice cream, or frozen crushed fruit which you may then add to drinks such as tea, water or fizzy drinks.

Class size: 10-12 students.

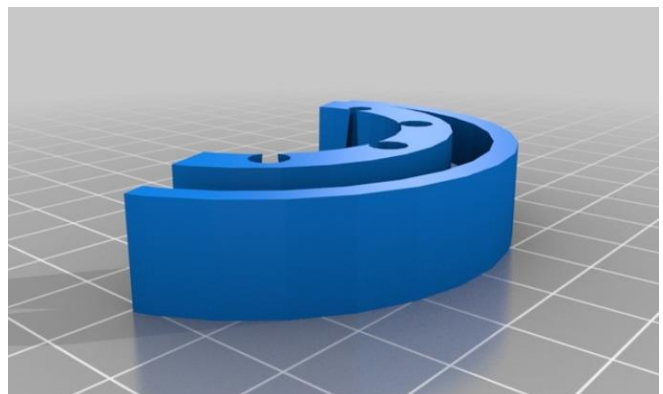
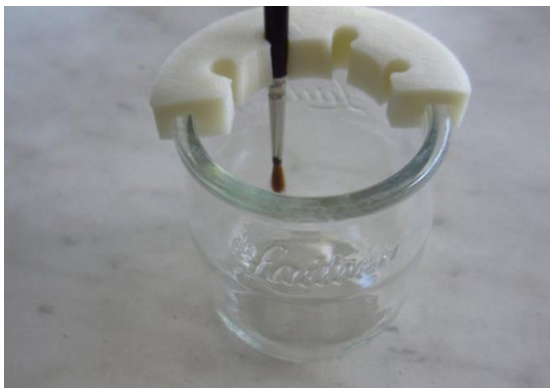
Individual work.

Duration: one day

- Material: PLA
- Dimensions: 19.46mm x 12.97mm x 4.57mm

Required tools:

- 3D printer
- Computer
- CAD software



12. Paint brush holder

Can be placed on top of a water pot or a glass so the brushes would not stain the surrounding surfaces with gouache or watercolour paint. Also, since brushes are hung above the water, they will not become dry as quickly.



Class size: 10-14 students.

Individual work.

Duration: one day

- Material: ABS (Acrylonitrile Butadiene Styrene)
- Colour: any
- Size: custom/set the size according to the pot
- Thin layers: 0.2mm
- Raft: Yes

Required tools:

- 3D printer
- Computer
- CAD software



13. Post-it note holder

Class size: 10-12 students.

Individual work.

Duration: one day

- Material: PLA
- Colour: Any

Required tools:

- 3D printer
- Computer
- CAD software



After the completion of practical tasks, the teacher may enquire:

- Which practical task was the favourite among students? The least favourite? Why?
- Which part of the practical exercise did they like the most?

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Tests

Questions for the final test

1. The first computer graphic program created in the 1960s was called

Correct answer: "SketchPad"

2. This program allowed people to and on the screen by using a special pencil.

Correct answer: draw and write.

3. What was the occupation of the man who created it?

Correct answer: He was a computer scientist.

4. The biggest sectors that use CAD daily are,, and

Correct answers: architecture, product design, graphic design and engineering.

5. CAD allows the user to build an entire model in an imaginary space and visualize properties such as,,,, and before this model is used.

Correct answer: height, width, distance, material and color.

6. What are the pros of Computer Aided Design?

1. 2. 3. 4. 5.

Correct answers: allows the user to easily imagine the result, the user can make their work quite detailed, permits optimization, can be easily adapted to be used in different fields, and tangible results.

7. What are the disadvantages of CAD? Fill in the blanks.

1. 2. 3.

Correct answers: It takes time to learn how to use it, High licensing fees (pricey) and requires powerful equipment to function at its best.

8. Fill in the blanks: At first, CAD was used for research purposes only but in thes, several big and companies started developing their own software

Correct answers: 1970s, automotive, aerospace engineering.

9. Industrial designers use CAD software not only to visualize an object but also to understand and verify its

- A) Beauty
- B) Design
- C) Functions



Correct answer: Functions

10. The Engineering Research Center of Brown University was designed by using BIM. What does the acronym BIM stand for?

Correct answer: Building information modeling.

11. When it comes to graphic design, CAD helps to by enhancing the design with typography, shapes and effects.

Correct answer: create visualisations

12. What is the title of an experimental software which utilizes AI and was created by Autodesk?

- A) Dreamweaver
- B) Dreamcatcher
- C) Dreamhunter

13. 3D printing is an technology used to manufacture parts.

Correct answer: additive

14. 3D printing technologies are also called ‘..... prototyping’.

- A) Smooth
- B) Fast
- C) Rapid

Correct answer: Rapid

15. 3D printing is often associated with: maker culture, hobbyists and

Correct answer: amateurs.

16. How many types of printing processes exist?

Correct answer: Seven.

17. What other manufacturing technology can be used for prototyping?

Correct answer: CNC machining

18. What is the Direct Energy Deposition process?

Correct answer: It is a process where molten metal is deposited and fused at the same time.

19. Which year onwards has 3D printing become popular as a hobby?

- A) 2007
- B) 2008



C) 2009

Correct answer: 2008

20. 3D printing was a key solution that accelerated industrial product through faster prototyping.

Correct answer: development

21. What year did Chuck Hull (thought of as the inventor of the 3D printer) file the patent for Stereolithography Apparatus (SLA)?

A) 1987

B) 1984

C) 1985

Correct answer: 1984.

22. The first patent for a device using UV light to cure photopolymers was awarded to Hideo Kodama in Japan. Which year was it?

A) 1961

B) 1971

C) 1981

23. Manufacturing methods developed before the 1980s are often referred to as manufacturing.

A) Industrial

B) Functional

C) Traditional

Correct answer: Traditional

24. The first commercial metal 3D printer was released in

A) 1990

B) 1992

C) 1994



25. Additive manufacturing builds up 3D objects by and 2D layers of material.

Correct answers: depositing and fusing.

26. One of the core strengths of 3D printing is

Correct answer: Parts can be produced in almost any geometry

27. One of the biggest disadvantages of 3D printing is that

- A) The finished product is not sturdy enough
- B) Several prints of the same part tend to differ slightly
- C) It is difficult to find suitable material

Correct answer: Several prints of the same part tend to differ slightly

28. The most commonly used 3D printing materials are and However, , and may also be used, depending on the situation.

Correct answer: Thermoplastic and thermoset polymers.

29. What other materials can be used, depending on the situation?

Correct answer: Metals, composites and ceramics

30. Fill in the blank. One of the ways of categorizing materials is by their: cheap, chemically resistant, dissolvable, flexible, durable, heat resistant, rigid, water resistant, UV resistant.

Correct answer: properties

31. What is the most widely used 3D printing technology?

- A) Powder bed fusion (PBF)
- B) Nanoparticle jetting (NPJ)
- C) Fused deposition modelling (FDM)



Correct answer: Fused deposition modelling (FDM)

32. Material Extrusion is a process that happens when molten thermoplastic is deposited through a nozzle

Correct answer: heated

33. VAT polymerization processes useto cure material in a prefilled vat.

Correct answer: UV light

34. Finish the sentence. Stereolithography (SLA), direct light processing (DLP) and continuous direct light processing (CDLP) are additive manufacturing processes that fall under the category of

Correct answer: vat photopolymerization

35. Name 3 of the most common methods for choosing the right 3D printing process?

Correct answer:

1. By required materials
2. By required functionality or visual appearance
3. By required accuracy or build size

36. The 3 main functional and visual design requirements are, and

Correct answers: smooth surface, strength and heat resistance

37. Direct energy deposition (DED) is usually used with

- A) Laser-engineered net shape
- B) Metal powders or wire
- C) Various plastics

Correct answer: Metal powders or wire

38. “Unlike the other 3D printing technologies, binder jetting does not require heat.” Is this statement true or false?

Correct answer: True.



39. What does EBM stand for?

- A) Electron beam melting
- B) Electron bead melting
- C) Electron bond melting

40. Fill in the blank:

“The number of available 3D printing materials grows quickly every year as
..... for specific material and mechanical properties stimulates the advancement in
material science.”

Correct answer: market demand

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